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ENGOBING OF WALL CERAMICS USING THE PLASMA SPRAYING METHOD

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A technology for engobing wall ceramics by plasma spraying of white-burning clay and kaolin powders of the fractional composition 30 – 250 μm is developed.

Particular importance is currently attached to exterior decoration of buildings, longevity and high quality of facing materials, and their architectural expressiveness. Engobed ceramics are among the most effective facing materials with good service and decorative properties.

Engobing is a widely known method of improving decorative and artistic properties of wall ceramics. The traditional engobing technology includes the operations of engobe preparation, deposition of the engobe on a solid surface, drying, and firing [1]. The latter two operations are time- and labor-consuming. A more efficient engobing technology entails the use of an open flame of a gas burner [2, 3]. The technology includes the stages of engobe preparation, drying, sintering, and gas flame treatment at a rate of 0.25 – 0.75 m/min. Engobe consumption in this case is 0.08 – 0.10 g/cm² [4]. The disadvantages of this method consist in the labor-consuming operations of preliminary preparation of dehydrated white-burning clay, engobe preparation, preliminary drying, and use of rather scarce materials, in particular, orthophosphoric acid (USSR Inventor's Certif. No. 675040).

The technology of plasma engobing of wall ceramics is the most efficient, economical, expedient, and advanced.

First, virtually any white-burning clay or kaolin can be used as the engobe. Second, the operations of engobe preparation, drying, and sintering are eliminated. Third, the duration of engobe deposition on the face surface of the wall ceramics is significantly shortened. Fourth, high-melting clays whose sintering temperature interval significantly exceeds the sintering temperature of the wall ceramics can be used for engobing.

The initial materials used to engobe ceramic bricks were Glukhovetskoe and Prosyantovskoe kaolins, and Chasov-Yarskoe clay, whose compositions are shown in Table 1. The fire resistance of Glukhovetskoe kaolin is 1770 – 1790°C, that of Prosyantovskoe kaolin is 1730 – 1770°C, and that of Chasov-yarskoe clay is 1710 – 1750°C. The granular and mineralogical compositions of the considered samples are given in Table 2.

Plasma spraying was performed on ceramic bricks 65 × 120 × 250 mm in size based on clay from the Ternovskoe deposit "Polyana" in Belgorod Region [5]. The face of the bricks was subjected to engobing by plasma spraying. The parameters of the UPU-8M plasma gun were as follows: working voltage 30 – 32 V, current strength 300 – 350 A. Argon acted as the plasma-forming gas, and its consumption was 0.0014 g/sec at a pressure of 0.25 MPa. Spray deposition of the kaolin and clay powders was carried out using a powder feeder designed by the authors. Experiments showed

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TABLE 1

Material	Weight content, %										
	SiO ₂	Al ₂ O ₃	TiO ₂	Fe ₂ O ₃	CaO	MgO	SO ₃	K ₂ O	Na ₂ O	SiO ₂ (free)	calcination loss
Kaolin:											
Prosyantovskoe	47.06	36.77	0.24	0.59	0.83	0.50	0.10	0.43	Traces	5.26	13.48
Glukhovetskoe	46.90	37.80	0.32	0.65	1.10	0.40	—	0.80	The same	Remainder	8.90
Chasov-yarskoe clay	54.21	30.50	0.36	1.29	0.70	0.90	0.17	2.35	0.47	13.01	9.05

TABLE 2

Material	Content, %, of particles of size, μm					Content, %		
	50 – 250	50 – 10	5 – 10	1 – 5	< 1	kaolinite	hydromica	quartz
Kaolin:								
Prosyantovskoe	6.5	26.8	12.3	27.6	26.7	92 – 96	1 – 2	5
Glukhovetskoe	0.5 – 0.8	6.7 – 9.3	13.7 – 18.5	15.0 – 20.0	45.0 – 55.0	90 – 95	1 – 4	5 – 7
Chasov-yarskoe clay	0.8 – 1.5	18.0 – 29.0	35.0 – 45.0	13.0 – 16.0	15.0 – 17.0	55 – 60	28 – 35	11 – 14

that kaolin and clay particles of size 30 – 250 μm are suitable for plasma spraying. Particle smaller than 30 μm are not suitable for plasma spraying, since they are trapped by the flow of the plasma-forming gas in spraying and are carried away from the surface of the wall ceramics. The distance from the nozzle of the GN-5r plasma burner to the surface of the ceramic brick was 200 – 250 mm. At a plasma treatment rate of 0.10 – 0.15 m/sec, the optimum engobe consumption was 12.35 – 18.53 g/sec. The decorative coating in this case was $1000 \pm 100 \mu\text{m}$ thick.

The engobing technology underwent industrial tests at production facilities of the Kolos JSC (Belgorod Region). The production line with an output of 4 million bricks per year includes the following technological operations (Fig. 1):

- sorting of intermediate products;
- laying bricks on an apron conveyor;
- transporting bricks to the plasma burner;
- plasma spraying of engobe on the face of wall ceramics;
- removal of engobed bricks from the apron conveyor;
- sorting and packing of finished bricks.

After engobing, the samples of wall ceramics were tested for resistance to cold and breaking strength using standard methods [6, 7]. The main factor affecting the adhesive strength of the coating and its resistance to cold is the thickness of the deposited engobe. Thus, as the coating thickness increases from 200 to 1500 μm , the adhesive strength decreases from 2.4 to 0.9 MPa, and the resistance to cold decreases from 34 to 18 frost-defrost cycles (Table 3). This is due to accumulation of residual stresses in the coating with

increasing thickness. Open porosity is absent from the coating, which is established by the “spot method”; however, the closed porosity is equal to 4.5 – 6.8%.

Under plasma treatment kaolins and white-burning clays become dehydrated, and mullite is formed and partly converted into a vitreous phase. Mullitization of kaolins is sufficiently well studied, and the thermodynamic constants of mullite formation at a temperature of 1823 K have been determined [1].

The authors investigated the phase composition of the kaolin and clay powders after plasma treatment. Powders of Glukhovetskoe and Prosyantovskoe kaolins and Chasov-Yarskoe clay were fed to a plasma burner via a special feeder, and the fused particles were collected in a container. An x-ray phase analysis shows that after plasma treatment Glukhovetskoe and Prosyantovskoe kaolins and Chasov-Yarskoe clay convert to mullite, quartz, and cristobalite. Petrographic studies showed that the particle surface becomes fused (a vitreous luster is clearly manifested) and is represented by aluminosilicate glass in which gaseous inclusions and microcracks are found. A fused particle is structurally a crystalline porous nucleus enveloped in a vitreous phase. The crystalline phase contains isolated and channel pores. The microcracks in the vitreous phase are formed due to the high rate of cooling. For the purpose of engobing, it is recommended that white-burning clay and kaolin powders and mixtures of them in any proportion be used. Depending on the color of the initial material, the face surface of wall ceramics can have shades of white, ivory, light gray, and beige.

A calculation showed the proposed technology of engobing wall ceramics to be economically efficient, since the cost per 1000 bricks is increased by 198 – 210 rubles, which is below the cost of 1000 hollow facing bricks of various col-

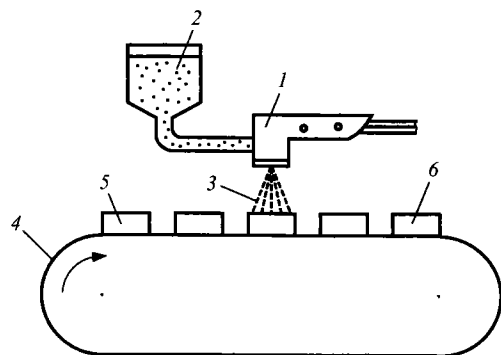


Fig. 1. Scheme of engobing wall ceramics: 1) plasma burner; 2) feeder with engobe powder; 3) flow of melted engobe particles; 4) apron conveyor; 5) brick before plasma engobing; 6) engobed brick.

TABLE 3

Sample	Thickness of deposited engobe, μm	Strength of adhesion of decorative coating to substrate, MPa	Resistance to cold, cycles
1	200 ± 50	2.4	34
2	400 ± 50	2.1	31
3	600 ± 50	1.8	29
4	800 ± 50	1.4	27
5	1000 ± 100	1.2	24
6	1200 ± 100	1.0	20

TABLE 4

Brick	Size, mm	Grade	Color	Surface	Price per 1000 units incl. VAT, rubles
Hollow		M 100		Smooth	1800
Solid	250 × 120 × 65	M 100 – 125	Red	Riffled	2700
Solid		M 150		Smooth	2904
Hollow thick	250 × 120 × 88	M 125	The same	Riffled	2442
Large-sized ceramic stone	250 × 250 × 138	M 125 – 150	"	The same	3822
Ceramic stone (double)	250 × 120 × 138	M 125 – 150	"	"	3822
Hollow facing	250 × 120 × 65	M 125 – 150	Straw	Smooth	2748
			Yellow		2610
			Apricot		2424
			Red		2304
			Dark red		2304
			Terracota		2802
			Brown		3948
Hollow thick (one and a half)	250 × 120 × 88	M 125 – 150	Straw	The same	3678
			Yellow		3840
			Red		3126
			Terracota		3810
			Brown		5370
Hollow "rodnichok"	250 × 120 × 65	M 125 – 150	Straw	Riffled	2646
			Yellow		2460
			Red		2348
			Terracota		2922
			Brown		3948
Hollow "turtle shell"	250 × 120 × 65	M 125 – 150	Yellow	The same	2976
			Apricot		2976
			Red		2394
			Terracota		2922
			Brown		4390
Profiled semicircular corner	200 × 120 × 65	M 125 – 150	Yellow	Smooth	4002
			Terracota		4002
			Brown		4500
Engobed by plasma spraying: hollow	250 × 120 × 65	M 100 – 125	Ivory	The same	2005
			Light gray		2005
			Beige		2005
solid	250 × 120 × 65	M 100 – 125	Ivory	Riffled	2905
			Light gray		2905
			Beige		2905

ors. Comparative costs of various types of wall ceramics are given in Table 4 (prices are given as of September 1, 1999, in Belgorod Region).

The engobed wall ceramics produced by plasma spraying satisfied the requirements of GOST 530-95. Thus, an environmentally safe highly efficient technology for engobing wall ceramics has been developed that uses white-burning clay and kaolin powders of a prescribed fractional composition.

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